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SPARK PLANING DAMAGE IN COPPER

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AND
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U. S. DEPARTMENT OF COMMERCE
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ABSTRACT

The damage to copper crystals, produced by spark planing operations, has been measured using a dislocation etch pit technique. The tabulated results show the depth of damage to vary from 0.7 - 1.1 mm on the coarsest planing range used, to 0.2 - 0.3 mm on the finest range. Two photomicrographs showing the etch pit density increase near the spark planed surface are included.

Key Words: copper, damage, dislocations, spark-erosion

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In connection with a project to measure the magnetoresistance of low-resistivity copper, it is necessary to prepare single crystal samples cut along each of the three major crystallographic directions. A commercial spark cutting machine* is used to first cut the three samples from the same single crystal ingot and then plane the samples to the correct orientation. To insure that these samples have electrical properties representative of the bulk material, it is necessary to know the extent of damage introduced by the spark machining operations and to remove this amount of material by chemical etching. This note describes the results of spark cutter damage studies on copper as revealed by dislocation etch pits.

The method of cutting is spark erosion, caused by a rapid series of spark discharges between the cutting tool and the work piece. This operation has often been referred to as relatively strain-free machining; however, very little quantitative data are available defining the extent to which physical damage is introduced. Cole, Bucklow, and Grigson [1], using x-ray diffraction and reflection electron microscopy, stated that their preliminary results on copper and aluminum indicated the damaged layer to be on the order of a few microns deep. Dislocation etch pitting, a more direct and more sensitive method for measuring depth of damage, was used by Palatnik, et al. [2] in their studies on bismuth, antimony, and zinc. Their results indicated that the damaged layer, surrounding a single crater formed by spark discharge, extended to a depth on the order of a few tenths of a millimeter. Other workers [3, 4] have published damage values for 3-1/4% Si-Fe and 70:30 brass.

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*Servomet Type SMD; Metals Research Ltd., Cambridge, England

The dislocation etch pit method was used in our work with copper. An annealed single crystal was first oriented using back-reflection Laue photographs and then planed with the spark machine to a (111) surface. The crystal was then etched in dilute HNO_3 for a time sufficient to remove all traces of damage. The etching time was determined by dislocation counts at intermediate stages of the nitric acid etch. Etching was terminated when no further reduction in dislocation density was observed. After etching in nitric acid, the sample was chemically polished for 1-3 minutes in a solution of 40ml HNO_3, 50ml $HC_2H_3O_2$ and 110ml H_3PO_4 at 60-70°C. The dislocation etchant (1MFeCl_3-6H_2O, 12MHCl, 0.25 MHBr) was that developed by Young[5] for use on (111) surfaces. The resulting background dislocation density was determined to be about $5 \times 10^6/cm^2$.

The crystal was then spark-planed with the gap voltage set at 180 volts on a plane perpendicular to the (111) plane. Damage from this operation is revealed by an increasing dislocation density approaching the newly planed surface which appears as the edge in Figs. 1 and 2. The defined depth of damage is arbitrary since the dislocation density increase is gradual from the crystal interior. It is defined here as the depth at which the density of dislocation etch pits has increased to the point of being unresolved. This corresponds to a density of about $5 \times 10^7/cm^2$. For comparison purposes, an area is marked in Fig. 2 where the average dislocation density was determined to be approximately $5 \times 10^6/cm^2$. As is seen in Fig. 1, the depth of damage is not constant along the length of the crystal. The damage depths tabulated in Table 1 show a spread corresponding to this variation. The values presented here are in good agreement with unpublished work of Hazzledine[6] who measured the damage in copper, as revealed by dislocation etch pits, produced by planing on two ranges (3 and 7) of the same model spark cutter.

Table I

Spark Cutter Damage

Cutting Range	Capacitor in Discharge Circuit	Depth of Damage (mm)
4	.25μf	0.7 - 1.1
5	.05μf	0.4 - 0.6
6	.01μf	0.3 - 0.4
7	10pf	0.2 - 0.3

Fig. 1 Spark damage, as revealed by dislocation etch pits, produced by planing on range 5. The (111) plane is parallel to the surface. The newly spark planed surface is perpendicular to the (111) plane and is shown as the edge in the figure.

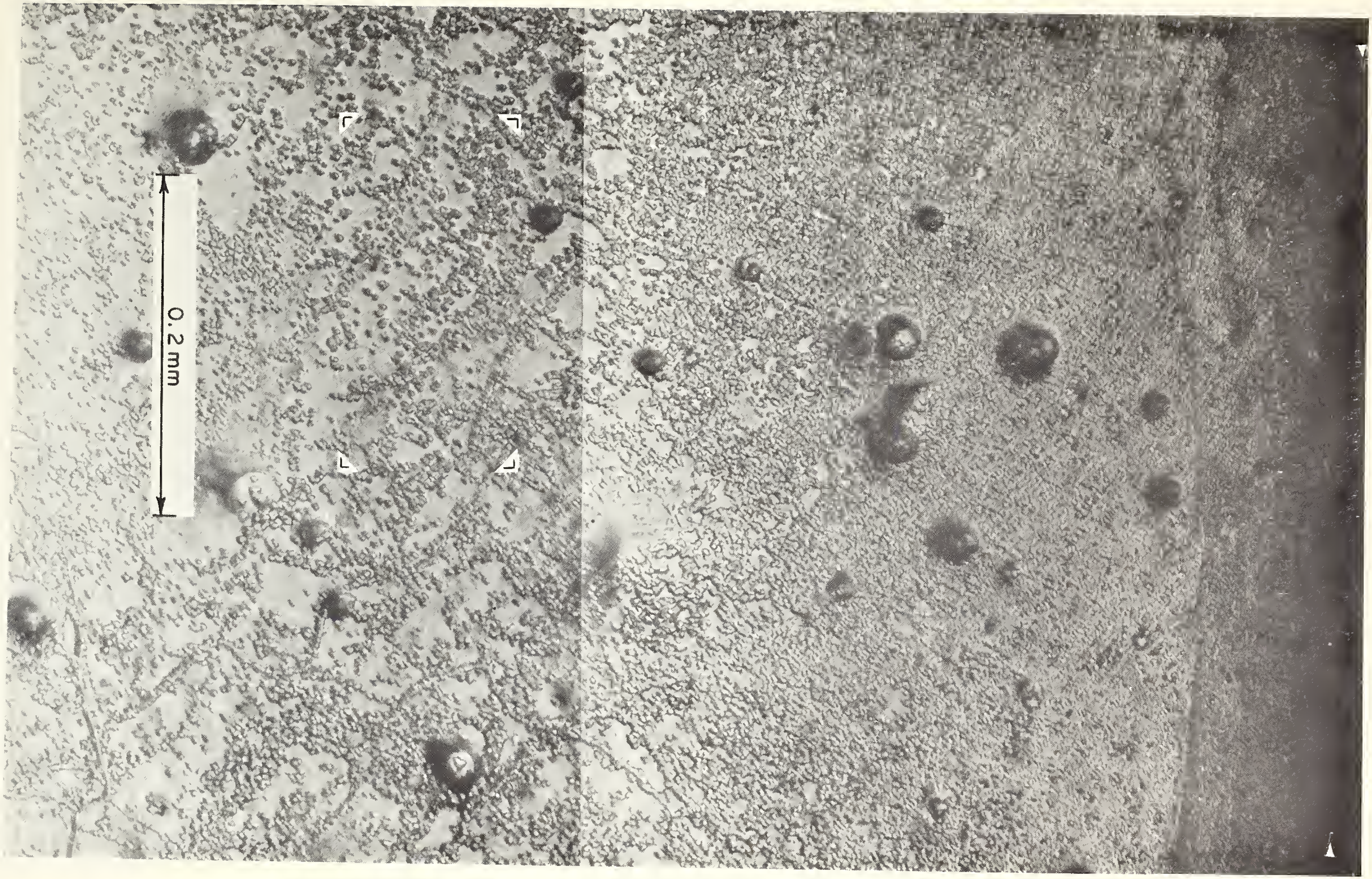

Fig. 2 Spark damage, as revealed by dislocation etch pits, produced by planing on range 6. The (111) plane is parallel to the surface. The newly spark planed surface is perpendicular to the (111) plane and is shown as the edge in the figure.

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